Chapter 2.1 SURFACE WATER MONITORING PROGRAMS

Ambient Water Quality Monitoring (AWQM)

At the core of determining the quality of the Commonwealth's waters are the data generated from the collection and analysis of ambient surface water samples. The Department has a long history of water quality monitoring beginning with the first sample collected in June of 1941. Over the years the focus of monitoring has been guided by various regulatory and assessment needs. With the development and implementation of the Water Quality Monitoring Strategy in 2000 the ambient monitoring program entered a new era of statewide multilayered network monitoring that is designed to produce representative high quality data that supports the evaluation, restoration, and protection of the quality of the Commonwealth's waters for the purposes of fishing, swimming, boating, drinking, and the propagation and growth of a balanced, indigenous, healthy, natural ecosystem. That strategy was revised in 2004 and formally accepted by the United States Environmental Protection Agency (USEPA). [1]

In order to achieve this goal, and satisfy scientific, legislative and aesthetic requirements related to the quality of the Commonwealth's aquatic resources, DEQ has established a series of specific objectives to identify and define the diverse functions of the Water Quality Monitoring Program.

Objectives:

1. Assessment and Remediation Objectives:

(**a**) Status Quo Characterizations and Assessments:

(1) Provide accurate, representative data for water quality characterization and assessment of all surface waters within the state.

(2) Establish consistent statewide siting, parameter selection and monitoring techniques, to ensure data reliability and the comparability of data.

(3) Assure that the frequency of sampling and the total number of observations collected are sufficient to provide adequate data for scientific, statistically based and defensible assessment procedures.

(4) Assure that, whenever possible, flow rates are determined simultaneously with the collection of water quality data.

(5) Monitor, according to a plan and schedule, all substances discharged into state waters that are subject to water quality standards or are otherwise necessary to determine water quality conditions.

(6) Continually evaluate the overall success of the Commonwealth's water quality management efforts.

(**b**) Impaired Waters / Remediation:

(7) Provide data to define the cause, severity and geographic extension of impaired waters:

(8) Provide adequate data for TMDL model development and validation.

(9) Provide adequate data, by means of follow-up monitoring, to evaluate the implementation of TMDL's and other best management practices.

(**c**) Variability, Trend Assessments and Forecasts:

(10) Provide adequate data and analytical procedures for short, medium and long-term statistical evaluation of water quality variation and trends within identifiable, geographically defined waterbodies.

2. Permit Objectives:

(11) Provide data for the calculation of permit limits for the issuance, re-issuance and/or modification of effluent discharge permits.

(12) When water quality problems are suspected, provide data to detect and document water quality

1 Millennium 2000 Water Quality Monitoring Strategy, Virginia Department of Environmental Quality, October 2004.

impairments and/or to evaluate permit adequacy, whether permitted dischargers are in compliance with permit limits or not.

3. Efficiency Objectives:

(13) Improve the efficiency of the Monitoring Program by minimizing resource requirements and the duplication of efforts, while maximizing the use of integrated data collected within and among state and federal agencies, public utilities, private enterprises and citizens groups for statewide water quality assessments.

(14) Increase the use of biological (e.g., benthic macroinvertebrates, fish, and/or aquatic vegetation assemblages), as well as fish tissue and sediment monitoring for specific assessments of water quality.

(15) Investigate, identify and characterize additional avenues of actual or potential water quality impairment, including ground water contribution and aerial deposition rates.

(16) Guarantee adequate Quality Assurance/Quality Control (QA/QC) procedures to provide precise, accurate and representative water quality data for all purposes.

4. Research Objectives:

(17) Provide data to validate special stream or site designations.

(18) Evaluate new methodologies for sampling, analyzing and assessing water quality.

(19) Provide data for other research objectives.

As a result of the implementation of the new strategy a monitoring network of multiple programs and special studies was identified and developed to include the following programs:

WATERSHED (AW) DEQ's ambient watershed network of stations represents the largest single section of the monitoring program. Detailed information on the purpose and objectives of these stations and their selection can be found in Section III.B. of the Monitoring Strategy.

COASTAL 2000 (C2) Coastal 2000 is the federally funded tidal probabilistic program designed by USEPA and sampled by VADEQ staff. Grant funding for this program is scheduled to end in 2006.

CHESAPEAKE BAY (CB) Chesapeake Bay Program identified in section III.E.1.of the strategy. The design of this program is through the Federal-Interstate Chesapeake Bay Program and encompasses a multi-state water quality characterization effort.

CITIZEN MONITORING (CM) These stations are monitored due to specific requests from the public, usually as a result of local concerns. Notification occurs in the fourth quarter of the calendar year with sampling scheduled to begin in the next monitoring year.

FACILITY INSPECTION (FI) Facility inspections are not specifically identified in the water quality monitoring strategy but are integral to determining compliance with discharge limits. Specific sample locations are not included in the monitoring plan but only estimated numbers of samples for the purpose of calculating annual budgets.

FRESHWATER PROBABILISTIC (FP) The freshwater probabilistic monitoring program covers the non-tidal free flowing waters of the state. The program is designed to answer the question of what is the overall water quality of the Commonwealth for free flowing streams.

FISH TISSUE (FT) Fish tissue and sediment monitoring program[2] conducted by central office staff from the Office of Water Quality Standards.

MERCURY (HG) Mercury Special Study Program paid for by the responsible parties.

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2 Virginia Department Of Environmental Quality, Water Quality Standards, Office Of Water Quality Programs 2001 Fish Tissue And Sediment Monitoring Plan, May 9th, 2001.

INCIDENT RESPONSE (IR) Incident response samples are the same as PC but are non-petroleum in origin.

POLLUTION COMPLAINTS (PC) Pollution complaints are special samples collected generally as a result of a petroleum spill.

REGIONAL BIOLOGICAL (RB) Biological monitoring program which focuses on the analysis of the benthic macroinvertebrate community as a tool to detect water quality conditions. The methodology follows the USEPA Rapid Bioassessment Protocol II and is described in section III.E.4. of the Monitoring Strategy.

RESERVOIR MONITORING (RL) Reservoir monitoring which is described in the Lake Monitoring Guidance[3] available at http://www.deq.virginia.gov/waterguidance/pdf/022004.pdf

SPECIAL STUDIES (SS) Special studies are identified by individual project plans and are generally specialized intensive targeted monitoring efforts designed to answer specific hypothesis related to water quality conditions.

TMDL (TM) TMDL monitoring stations are those stations associated with the development of a TMDL and subsequent implementation plan for segments listed on the 303(d) list.

TREND (TR) Trend stations are those long term stations sited for permanent monitoring for the purpose of detecting water quality trends for a wide variety of environmentally important water quality parameters.

CARRYOVER (TW) Those stations with insufficient data for assessing and usually are those stations with small data sets during an assessment cycle that indicate a potential problem. These stations are considered carryover stations and will be sampled until sufficient data is available to determine the water quality conditions.

Data Summary

Between January 2000 and December 2004 DEQ staff collected multiple samples at 4375 stations. From these stations, the number of independent observations for the common field measurements was 43,720 for temperature, 43,161 for pH, 44,270 for dissolved oxygen, 39,171 for specific conductivity, and 17,547 for salinity. These samples were analyzed for a variety of chemical constituents including nutrients, bacteria, metals, pesticides, herbicides and toxic organic compounds; 612 different parameters were sampled for a total of 1,040,907 data points.

The number of stations representing a particular type of stream segment, the types of samples collected, the parameters analyzed, and the sampling frequency all vary depending on site conditions and program emphasis. A detailed report of sample locations, matrices, parameters, and frequency is available in the Annual Monitoring Plans at http://www.deq.virginia.gov/water/reports.html.

Each basin summary, found in Chapter 3.2 of this report, lists the ambient water quality monitoring (AWQM) and biological (benthic) monitoring summary data within the basin. Summaries of the sampling data collected at each station during the reporting period are provided as a supplement to this report and can be found on the DEQ water webpage http://www.deq.virginia.gov/water.

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3 Lake Monitoring Guidance, Virginia Department of Environmental Quality, December 1999. Revised in 2002

Estuarine Probabilistic Monitoring Program (Coastal 2000)

Background:

Virginia's estuarine probabilistic monitoring module was initiated in the summer of 2000 with a five-year grant (CR-828544-01 – period 2000-2004) from EPA's "National Coastal Assessment (NCA) Program", formerly known as the "Coastal 2000 Initiative". This original, five-year effort was defined under the terms of a proposal titled "Monitoring the US Atlantic Coast: Assessing Virginia's Estuaries and Tidal Tributaries to the Chesapeake Bay and the Atlantic Ocean", submitted to the US-EPA in the spring of 2000. Specific field methodologies and Quality Assurance requirements of the Coastal 2000 / National Coastal Assessment Program are described in the EPA documents "National Coastal Assessment Field Operations Manual" (EPA 620/R-01/003) and "National Coastal Assessment Quality Assurance Project Plan 2001-2004" (EPA/620/R-01/002).

Purpose:

The original goals of the National Coastal Assessment (Coastal 2000) Program were summarized as:

- Assess the ecological condition of estuarine resources,
- Determine reference conditions for ecological responses/stressors, and
- Build infrastructure in EPA Regions and participating states.

Additional, more specific federal objectives were to:

- Assess the health or condition of the estuarine waters of the United States and track changes in that condition through time,
- Assess the health or condition of the estuarine waters of the various coastal states and track changes in that condition through time,
- Utilize the approach to identify reference conditions for estuarine waters in the United States, and
- Utilize existing state monitoring programs as appropriate

The geographic extent of the Estuarine/Coastal ProbMon Program is restricted to the eastern-most regions of the state. It is coordinated through the DEQ Central Office in Richmond and is carried out primarily by the Piedmont (PRO - Glen Allen) and Tidewater (TRO - Virginia Beach) Regional Offices. A small proportion of the estuarine probabilistic sites fall within the geographic jurisdiction of the Northern Virginia Regional Office (NVRO) in Woodbridge; however due to the small number of sites involved (1 or 2 sites annually), and logistical and training considerations, PRO assumes the primary responsibility for sampling while NVRO personnel may accompany and aid them in the field.

At the state level, the Virginia DEQ defined its agency goals and objectives relative to its comprehensive statewide Water Quality Monitoring (WQM) Program. Each participating DEQ region (PRO & TRO) needs to complete its assigned probabilistic stations in order for DEQ to reach defensible conclusions about estuarine water quality from a statewide perspective.

Monitoring Design (Site Selection, etc.):

The sampling strata for tidal tributaries have been geographically defined, by estuary size and drainage location, and a set of randomly selected sampling sites are provided annually by the EPA/ORD Gulf Ecology Division (GED) Laboratory in Gulf Breeze, Florida, upon request.

The two principal sampling strata consist of (1) small tidal tributaries to the Chesapeake Bay and its major tributaries and (2) tidal tributaries and embayments of the Atlantic coast and Back Bay/North Landing River (which discharge into Pamlico/Albemarle Sounds, North Carolina). The major tidal tributaries to Chesapeake Bay (the Potomac, Rappahannock, York and James Rivers), as well as the Bay mainstem, are effectively characterized by the probabilistic monitoring of Virginia's Chesapeake Bay Program. Periodically, these larger waters are also included in the NCA sampling design for the purpose of integration into the nationally standardized coastal assessment.

In the first year of sampling, 35 sites were selected in Virginia's portion of the Chesapeake Bay mainstem and the tidal portions of its major tributaries (Rappahannock River, York River, James River, &

Elizabeth River - the tidal portions of the Potomac River mainstem are entirely in the state of Maryland). In order to better characterize smaller estuarine subdivisions, DEQ has in subsequent years (2001-2004) emphasized, and will continue to emphasize, minor tidal tributaries to the Chesapeake Bay, the Atlantic Ocean, and to Pamlico/Albemarle Sound by sampling at 50 sites annually. Virginia's participation in the interstate Chesapeake Bay Program already provides adequate probabilistic monitoring for the characterizations of the Chesapeake Bay mainstem and its major tidal tributaries (e.g., lower Potomac, James, York, and Rappahannock Rivers). The weighting of the current sampling design guarantees that each year approximately 70% of the sites (~35 stations) are selected in the Chesapeake Bay drainage and approximately 30% (~15 sites) are selected in coastal drainages. This will assure that a minimum of approximately 60 sites will be available to characterize the coastal estuary resource class by the end of the fifth year of the program.

Core and Supplemental Water Quality Indicators:

At present, with the resources provided by the EPA NCA/Coastal 2000 Grant, estuarine probabilistic stations are sampled for the complete suite of parameters described in the National Coastal Assessment QAPjP cited above, as well as additional parameters utilized by the Chesapeake Bay Program. The total suite of water column parameters includes profiles of temperature, pH, DO, salinity and Photosynthetically Active Radiation (PAR), as well as samples for chlorophyll, nutrients and suspended solids measurements at near-surface, mid-depth and near-bottom. In addition, homogenized sediment samples are collected for local (DCLS) analyses of particle size and total organic carbon (TOC), as well as for metals and organic contaminant analyses and toxicity testing at EPA-contracted laboratories. A separate, 0.04 m^2 sediment sample is collected and sieved in the field for the later identification of macroinvertebrate benthic infauna species, to complete the sediment 'triad' for 'weight-of-evidence' ecological evaluations and assessments. EPA Grant funds also currently provide for the contracting of the Fisheries Science Laboratory at the Virginia Institute of Marine Science (VIMS) for fish trawls. These trawls are used to collect fish community-structure data, epibenthic organisms, incidental fish for pathological examinations, and targeted fish species for the analyses of metals and organic contaminants in whole fish. (Please refer to the "NCA-C2000 Overview" for an overview of the core ecological and chemical parameters stipulated by the National Coastal Assessment (Coastal 2000) Program and "Estuarine ProbMon Local Parametric Coverage" for a complete list of locally analyzed water column and sediment parameters.) Beginning in the summer of 2003, DEQ started supplementing the NCA core indicators with additional sampling for bacteria (fecal coliform, E. coli, and enterococci) as well as for dissolved trace metals.

Sample handling and shipping varies with the type of sample and its final destination for analysis. All samples are collected from boats anchored at the monitoring sites and are appropriately labeled and stored on wet ice at 4^{o} C during transport to the responsible DEQ Regional Office. Samples to be analyzed at the Virginia State laboratory (DCLS) are maintained on ice and shipped daily to Richmond by overnight courier service. Such samples are received and processed within 24 hours of collection. Analyses are completed within the holding time specified in the pertinent QAPjPs and EPA analytical method descriptions, after which the resultant data is entered into the DCLS LIMS system. Analytical results are subsequently transmitted to and permanently stored in the DEQ CEDS 2000 database on a daily basis. Turnaround time from sample arrival at DCLS to receipt of analytical data varies from 48 hours to 21 days, depending upon sample type.

Sediment samples that are to be analyzed chemically and toxicologically by EPA-contracted laboratories are held under refrigeration at DEQ Regional Offices and are shipped to Richmond by courier on a weekly basis. Samples from the previous week are united and shipped via overnight air to the EPA Gulf Ecology Division (EPA/GED) laboratory at Gulf Breeze, FL, from where they are redistributed to the appropriate contracted laboratories. Benthic infauna samples are preserved in (10%) buffered formalin as soon as they are collected and are maintained at DEQ Regional Offices until the end of the field season (early October). They are then united at the DEQ Central Office in Richmond and shipped to EPA/GED for subsequent transshipment. Turnaround time for the receipt of analytical results from EPA-contracted laboratories varies from one year to two years or more, depending upon sample type and EPA QA/QC procedures prior to the relay of data to DEQ.

Data related to fish community structure, epibenthic invertebrates, and habitat collected by VIMS trawl sampling are immediately entered into their onboard SAS database during the process of collection. Target fish species selected for chemical tissue analyses are individually labeled and wrapped and maintained on ice during transport to the laboratory. Once there, they are frozen and maintained until the end of the field season (October). They are then shipped overnight, on dry ice, to EPA/GED for storage and later transshipment. Fish pathology specimens are maintained in Dietrich's solution until the end of the field season and are subsequently shipped to EPA/GED. Fish community, epibenthic macroinvertebrate and habitat data are united into a final report which VIMS sends to DEQ soon after the end of the field season, generally in October or early November.

Turnaround time for fish tissue chemical data and fish pathology data from EPA-contracted laboratories is currently at least two years.

Frequency/Duration:

As is typical of probabilistic survey programs, monitoring sites are sampled only once, after which new sites are randomly selected each of the following year(s). Under the conditions defined by the NCA QAPjP, sampling occurs during the summer months, from 1 July through 30 September. This period also coincides with the sampling "window" defined for the use of the Chesapeake Bay Program's "Benthic Index of Biological Integrity" (B-IBI), which is utilized to evaluate the ecological health of the benthic community.

DEQ's Estuarine Probabilistic Monitoring Program was proposed and developed as a major component of the agency's Ambient Water Quality Monitoring Program, and is fully implemented at this time. The resources currently provided by the EPA Coastal 2000 Grant, which facilitated the initiation of the program in 2000, terminated at the end of September 2004, DEQ has continued the Estuarine ProbMon Program with state funding beginning in 2005, with a slightly reduced suite of parameters.

Quality Assurance Measures:

DEQ's field and laboratory activities adhere to QA/QC protocols specified in the National Coastal Assessment Field Operations Manual (EPA 620/R-01/003) and the National Coastal Assessment Quality Assurance Project Plan 2001-2004 (EPA/620/R-01/002), except where specific variations have been authorized by the Regional NCA QA Officer. Authorized departures include the use of submerged pumps and hoses for the collection of subsurface water samples and vacuum field-filtration of nutrient and chlorophyll samples. Both of these procedures are specifically described in the corresponding sections of the QAPjP and SOPs for Virginia's Chesapeake Bay Monitoring Program.

DEQ requires that a minimum of 10% QA samples (field duplicates, field blanks, etc.) be collected at estuarine ProbMon field sites for all locally analyzed parameters. At present, three QA sites are randomly selected annually per DEQ Regional Office, for a total of six QA sites among the 50 sites sampled (12%).

Data Management:

Both samples and the resultant data collected within the National Coastal Assessment Program follow diverse pathways. Standard procedures for the transportation and delivery of samples to the Virginia Division of Consolidated Laboratory Services (DCLS) and of sample shipment to EPA/ORD/GED at Gulf Breeze, FL are described above.

The data flow and data management for water and sediment samples analyzed by DCLS follow pathways and turnaround times as described for the WQM Program in general. Analytical results are QA'ed by DCLS and stored in their LIMS database. Results that are complete and certified there are subsequently shipped electronically to the DEQ FTP site for upload into the CEDS 2000 database on a daily basis.

Currently, all data from locally (DCLS) analyzed samples reside in DEQ's CEDS 2000 database. A list of DCLS parameter group codes, analyte names and analyte STORET codes is provided in the table "Matrix of Local Estuarine ProbMon Parameters". The turnaround time from receipt of samples at the laboratory until data arrives in the database varies from 48 hours to 21 days, depending upon sample type. All analytical results receive a QA review at DCLS, prior to shipment to the DEQ database, and another QA review by programmed algorithms (data range screenings, etc.) within the CEDS database. Data that are 'flagged' by the automated screening procedures undergo an additional evaluation by DEQ's QA Officer. Whatever questions arise concerning the location, date and time of samples arriving at DCLS, or about the accuracy of DCLS data transmitted to the CEDS database, are resolved immediately via e-mail and voice communication between laboratory personnel and monitoring personnel at the DEQ Central or appropriate Regional Office.

Looking to the Future:

The National Coastal Assessment Program (Coastal 2000 Initiative) was instituted by EPA's Office of Research and Development (ORD) as an experimental program in 2000. The original five-year program was so successful and so well accepted by the participating coastal states, that it is currently being transferred to EPA's Office of Water (OW) as a permanent component of its national water quality monitoring strategy. An interim two-

year grant will support the program (at a reduced level) during the 2005-2006 transition. After that, the program will be supported via the normal § 106 federal grant process.

Beginning in the summer of 2005, portions of this program were coordinated with and integrated into the Chesapeake Bay Program's (CBP) probabilistic benthic monitoring program. Probabilistically-collected sediment-related parameters (sediment chemistry, sediment toxicity and benthic community structure – the 'Sediment Quality Triad' or SQT) from the minor tidal tributaries will supplement CBP efforts in the major tidal tributaries and mainstem of Chesapeake Bay. Use of the SQT will facilitate the characterization and aquatic life use assessment of these minor tidal tributaries, where sample sizes are generally insufficient to apply the formal statistical assessment method utilized for the Benthic Index of Biological Integrity (B-IBI) in larger Chesapeake Bay assessment units (segments).

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Freshwater Benthic Macroinvertebrate Monitoring Program

Virginia's freshwater biological monitoring program began in the1970's to fulfill requirements of the Federal 106 grant agreement. DEQ uses benthic macroinvertebrate communities to assess the ecological health of freshwater streams and rivers. Benthic macroinvertebrates are larger-than-microscopic invertebrate organisms such as insects, crustaceans, snails, mussels, or worms that inhabit stream bottoms.

Biological monitoring using benthic macroinvertebrates is an invaluable tool for evaluating the overall, temporally integrated effects of the water and sediment quality in streams and rivers. Benthic macroinvertebrate communities integrate water quality both through time and the effects of different pollution stressors, thus providing a holistic measure of their aggregate impact, including antagonism and/or synergism among chemical and physical pollutants. Because of their sedentary nature, macroinvertebrates are good indicators of localized conditions. Most species have a complex life cycle of approximately one year or more and therefore integrate the effects of fluctuations in water quality over time in which periodic conventional water quality surveys may miss. In essence, benthic macroinvertebrates are considered to be virtual "living recorders" of water quality conditions over time. The structure and functioning of macroinvertebrate communities are also extremely sensitive, and may exhibit responses to water quality parameters for which specific criteria or standards have not been defined, for which chemical analyses are not normally performed, or for which biological tolerance is below chemical detection limits.

DEQ's biological monitoring program examines over 150 stations annually. Reasons for bioassessments include but are not limited to: targeted monitoring, probabilistic monitoring, tracking local pollution events, follow-up on waters of concern identified through volunteer citizen monitoring, and TMDL monitoring. Data from the biological monitoring program are used in the periodic review and assessment of state waters as required by Section 305(b) of the Clean Water Act. Benthic macroinvertebrate monitoring is used in assessing the designated use of state waters established in 9 VAC 25-260-10 A. that states in part that "All state waters, including wetlands, are designated for the following uses: ……the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them….." .

DEQ uses two bioassessment indices to assess the biotic integrity in non-tidal freshwater streams and rivers in Virginia. In the Coastal Plain, which is characterized by low gradient streams east of the fall line, the Coastal Plain Macroinvertebrate Index (CPMI) is used. This multimetric index was developed in 1997 by the Mid-Atlantic Coastal Streams (MACS) workgroup. The CPMI is a multimetric bioassessment index which was calibrated for low gradient Coastal Plain streams which exhibit different expected benthic macroinvertebrate communities from non-coastal streams.

For non-coastal streams, biological assessment of the benthic macroinvertebrate community is based on the methods described in the EPA's Rapid Bioassessment Protocols for Streams and Rivers (RBP II) document (Plafkin et al. 1989). Unlike the CPMI which uses an established reference condition for calculation of the metrics, the RBP II requires a paired reference stream for the calculation of the metrics. The reference stream that is chosen should represent the best available or least disturbed conditions possible for the ecoregion in which the stream to be assessed is located.

In 2003, a stream condition index was developed for Virginia freshwater non-coastal streams by USEPA's contractor Tetra Tech, Inc. using historical data collected in Virginia at reference and stressed streams in 1994-1998, and was tested against additional data collected in 1999-2002. This review has resulted in the development of the Virginia Stream Condition Index (VSCI) for use in assessing wadeable non-coastal streams. It is based upon recent advances in bioassessment methods contained in "*Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, Second Edition*" (Barbour et al. 1999). The VSCI, a multimetric calculation of benthic integrity converted into a single numerical score, resulted in a single reference condition for the entire non-coastal portion of the Commonwealth against which all future benthic samples will be compared. The development of this index is considered a significant step in the advancement of the biomonitoring program to address a wide range of monitoring and assessment needs. An Academic Advisory Committee (AAC) representing a cross-section of Virginia colleges and universities has been assembled to review the technical merits of its development, to ensure the applicability of the VSCI, and to provide recommendations toward further testing and refinement of the index.

The 2006 Integrated Report will be assessing the biological data using the same methods and metrics as have been used by DEQ in previous 305(b) reports. DEQ intends to finalize this Stream

Condition Index and use this new index to review the benthic biological data and make assessments of the biological data for the 2008 Integrated Report.

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Estuarine Benthic Macroinvertebrate Monitoring Program

Benthic organisms are important secondary producers, providing key linkages between primary producers (phytoplankton) and higher trophic levels (crabs, bottom feeding fish and water birds). Benthic invertebrates are among the most important components of estuarine ecosystems and may represent the largest standing stock of organic carbon in the Chesapeake Bay. Benthic organisms, such as hard clams and soft-shell clams, are economically important. Others, such as polychaete worms and shrimp-like crustaceans, contribute significantly to the diets of economically important blue crabs and bottom-feeding juvenile and adult fish such as spot, croaker, striped bass, and white perch.

The objectives of the Chesapeake Bay Estuarine Benthic Macroinvertebrate Monitoring Program are:

1. To characterize the health of regional areas of the lower Chesapeake Bay as indicated by the structure of the benthic community.

2. To conduct trend analyses on long-term data, at fixed- point stations, to relate temporal trends in the benthic communities to changes in water and/or sediment quality. The trend analyses will be updated annually as new data are available.

3. To warn of environmental degradation by producing an historical data base that will allow annual evaluations of biotic impacts by comparing trends in status within probability-based strata and trends at fixed-point stations to changes in water and/or sediment quality.

21 fixed-point stations are sampled one time per year (September) and there is one probabilistic summer sampling per year.

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Fish Tissue and Sediment Monitoring Program

DEQ monitors concentrations of chemical contaminants, including heavy metals and organic pollutants, in fish and shellfish tissue in order to assess the human health risks for individuals who may consume fish from state waters. Additionally, sediment samples are also collected at each sample station and are analyzed for the same pollutants. The sediment data are used to help locate a source of pollution where the fish tissue data indicate a concern. The sediment data are also used to identify potentially impaired aquatic ecosystems.

In the fish tissue-monitoring program, a two-tiered sample strategy is followed which is consistent with federal guidance for fish tissue contamination monitoring programs.

Tier I is a screening study of a relatively large number of sample stations to identify sites where concentrations of contaminants in the edible portions of fish indicate potential health risks to human consumers. Sediment samples are also collected to assess whether stream sediments are contaminated to a degree that poses a potential for aquatic ecosystem impairment. Tier I stations are selected using a rotational river basin approach of all the river basins in Virginia. Until 1996, approximately 25-30 stations were selected among two river basins each year as the routine monitoring. The Code of Virginia § 62.1-44.19.5 requires maintenance of the 1996 level of tissue and sediment sampling which equates to a minimum of 24 fish sample stations per year. Since 1996 the following number of stations have been sampled for fish and sediment; 1997 (43 stations), 1998 (54 stations), 1999 (58 stations), 2000 (72 stations), 2001 (96 stations), 2002 (98 stations), 2003 (74 stations), and 93 stations in 2004. A variable number of some additional stations were sampled for sediment each year.

Several criteria are used to select the sample stations and include correspondence with the DEQ-Waste Division to identify contaminated waste sites that may impact tissue and sediments in aquatic environments. These are regional office recommendations, extensive literature searches, important recreational and/or commercial fisheries (Department of Game and Inland Fisheries, 1996), close proximity to point source discharges, and coverage of the entire watershed, i.e. headwater as well as higher order streams. Routinely, a minimum of three species of fish (top level predator such as a largemouth bass, mid-level predator such as a bluegill, and a bottom feeder such as catfish) are collected at each station. Edible filets from five to ten adult specimens of each species are composited into one sample, resulting in a minimum of three tissue samples per station. Depending on availability of additional funds and variability of species available, four or five species may be sampled at some stations.

Tier I analytical results for fish tissue are expressed in wet-weight and are compared to fish tissue values that are computed using EPA risk assessment techniques for noncarcinogen and carcinogen effects. The fish tissue values are calculated based on the same toxicity values and assumptions for average fish consumption rate, body weight and an acceptable extra cancer risk of 10^{-5} that were used in calculating the Virginia water quality criteria designed for the protection of human health from consumption of contaminated fish. These fish tissue values represent the fish tissue concentration that the water quality criteria are intended to protect against. Occasionally, additional pollutants are sometimes detected in fish tissue for which Virginia does not have water quality criteria; or the toxicological information on the chemical has been revised and the water quality criterion has not been updated yet. In this case, an updated fish tissue screening value is calculated and used to assess the data.

Analytical results for contaminants in sediments are expressed in dry-weight and are compared to freshwater Consensus-Based Probable Effects Concentrations (PECs), or in salt and estuarine waters effects range-median (ER-M) screening values as provided by the National Oceanic and Atmospheric Administration are used to assess the potential effects of sediment contamination to aquatic life. Specific contaminants can be found in Appendix E of the 2006 Assessment Guidance Manual at the DEQ website **http://www.deq.virginia.gov/wqa/.**

For additional information and data from previous years of sampling visit the DEQ website at **http://www.deq.virginia.gov/fishtissue/html.**

If tier I results indicate problems may exist, then a second more intensive tier II study is initiated to determine the magnitude and geographical extent along with potential source(s) of contamination in the fish and/or sediment.

The program fulfills the Clean Water Act § 106 United States Environmental Protection Agency (EPA) grant requirements for the collection of fish tissue and sediment. Data generated by the program are used by

the Virginia Department of Health to determine the need for fish consumption advisories and/or bans. Data are also used by the DEQ and other state and federal agencies to assess the environmental quality of Virginia's waters. The following is a list of those compounds analyzed.

Metals:

Arsenic
Beryllium
Cadmium
Chromium
Copper
Lead
Mercury
Nickel
Selenium
Silver
Thallium
Zinc

Pesticides:

Aldrin
Dieldrin
Endrin
DDT
DDE
DDD
Chlordane
Heptachlor
Heptachlor epoxide
Hexachlorobenzene
Methoxychlor
Nonachlor
Dicofol
Endosulfan (alpha)
Endosulfan (beta)
Total PCBs
Toxaphene
Benzene hexachloride (alpha)
Benzene hexachloride (beta)
Lindane
Benzene hexachloride (delta)
Chlorpyrifos-methyl
Mirex
Oxychlordane
Pentachloroanisole
Polybrominated diphenyl ethers (BDEs)

Other Organics:

Acenapthane
Acenaphthylene
Anthracene
1,2 Benzanthracene
Benzo (a) pyrene
3,4 Benzofluoranthene
Benzo (k) fluoroanthene
1,1,2, Benzoperylene
4-Bromophenyl phenylether
4 Chloro-3-methylphenol
2-Chloronaphthalene
4-Chlorophenolphenylether
Chrysene
Dibenzo (a,h) anthracene
3,3-Dichlorobenzidine
2,4-Dimethylphenol
Diethylphthalate
Dimethylphthalate
Fluoranthene
Fluorene
Ideno (1,2,3-cd) pyrene
Naphthalene
4,6-Dinitro-2-methylphenol
N-Nitrososdiphenylamine
N-Nitroso-di-N-propylamine
Phenanthrene
Bis (2-ethyl-hexyl) phthalate
Butylbenzylphthalate
Di-N-butylphthalate
Di-N-octylphthalate
Pyrene
1,2,4-Trichlorobenzene
Total PAHs
Benzo (e) pyrene
Benzo (b) fluoranthene
Benzo (a) anthracene
Benzo (g,h,I) perylene
Benzo (I) fluoranthene

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BEACH Monitoring Program - Virginia Department of Health (VDH)

Introduction

The "Beaches Environmental Assessment and Coastal Health (BEACH) Act" of 2000 amended Section 303 of the Federal Water Pollution Control Act (33 U.S.C. 1313) by specifying monitoring and reporting requirements for pathogens and pathogen indicators in coastal recreational waters for the purpose of protecting public health and welfare. An additional requirement of this Act was the publication of a list of "discrete coastal recreation waters adjacent to beaches or similar points of access that are used by the public." The resultant "National List of Beaches" [http://www.epa.gov/ost/beaches/list/list-of-beaches.pdf] (already outdated) was first published by the U.S. EPA in March of 2004. A current list of the beaches monitored in Virginia is available and cited below. The requirements of the BEACH Act apply only to states and tribes that have coastal recreational waters, defined by the Clean Water Act (Section 303(c) as the "…Great Lakes and marine and estuarine coastal waters that are designated by a state or tribe for use for swimming, bathing, surfing, or similar water contact activities…"

Within the Commonwealth of Virginia, the Division of Zoonotic and Environmental Epidemiology (DZEE) of the Virginia Department of Health (VDH) initiated the BEACH Monitoring Program [http://www.vdh.virginia.gov/whc/external_whc/BeachMonitoring.asp] in 2002. In addition to the immediate reporting requirements and public notices relative to swimming advisories, results obtained by the VDH are communicated to DEQ for inclusion in the agency's biennial 305(b)/303(d) Water Quality Assessment Reports. The specific 305(b) assessment methodologies for using (1) swimming advisories and/or (2) the enterococci concentration data from the BEACH Monitoring Program was discussed by VDH and DEQ. The final decision on appropriate methodologies is incorporated into the Assessment Guidance Manual for the 2006 Integrated 305(b)/303(d) Report.

The BEACH Monitoring Program in Virginia is designed to provide seasonal monitoring coverage of coastal and Chesapeake Bay beaches within the Commonwealth. A public bathing beach is defined by the Code of Virginia (1980, c.428, section 10-217, 10.1-705) as "a sandy beach located on a tidal shoreline suitable for bathing in a county, city or town and open to indefinite public use." Based on these characteristics, forty-seven public beaches were identified prior to December of 2003, by which time their locations were communicated to EPA for the National List of Beaches. A List of Virginia Beaches [III-B-9-1.doc](47 beaches), extracted from the original 'National List of Beaches' along with additional EPA contact information, is provided here as a convenience. As of July 2004, a total of 47 Virginia beaches were being monitored by the BEACH Program (Actively Monitored Sites in the Virginia BEACH Program – July 2004 [III-B-9-2.xls]). The rational for identifying and enumerating individual beaches is discussed below, in the section on 'siting.' The localities participating in this program include the cities of Virginia Beach, Norfolk, Hampton, Newport News, and Yorktown, and King George County, Gloucester County, and Northampton and Accomack Counties on the eastern shore of Virginia.

Purpose

Monitoring of beaches is conducted to protect human health. Weekly monitoring is conducted to determine if levels of indicator bacteria (enterococci) meet the requirements of the State Water Quality Standards.

Monitoring Design and Station Siting

The number of sampling stations at a beach is based on EPA guidance available in PDF format from the following web page: http://www.epa.gov/waterscience/beaches/grants/guidance/index.html. The rationale for siting and enumerating individual beaches is based on beach size and whether (1) it is small and is treated as a single entity for swimming advisories, or (2) if it is more extensive and individual sections may be closed independently. In summary, the current list of responsible health districts and beaches includes:

Rappahannock Health District (Fairview Beach) - 1 beach
Peninsula Health District (Newport News, Yorktown) - 5 beaches
Hampton City Department of Health - 3 beaches
Norfolk Department of Public Health - 9 beaches
Virginia Beach (24 miles long) - 24 beaches
Three Rivers Health District (Gloucester Point) - 1 beach

Eastern Shore Health District - 4 beaches

Total = 47 beaches

Samples are taken in the middle of a typical bathing area. If the beach is short, samples are taken at a point corresponding to each lifeguard chair or one sample for every 500 meters of beach. (Sample results from several sites in the same beach unit may be united into a single arithmetic average for comparison with the Water Quality Standard and evaluation for swimming advisories - see below.) If the beach is long (more than 5 miles) samples are spread out along the entire beach (e.g., Virginia Beach, which is 24 miles long, has 24 sampling stations spaced one mile apart). Locations of sites are identified by coordinates of latitude and longitude and remain uniform from year to year in order to maintain a permanent, long-term database on beach water quality.

The most updated information relative to the BEACH Monitoring Program, including maps of many of the specific sampling sites, the most recent bacterial count results, and a list of swimming advisories, may be found on the VDH WebPages at: Virginia Department of Health.

Frequency

Beaches are sampled for indicator bacteria on a weekly basis from mid-May through September. When the Water Quality Standard at a specific beach is exceeded, or when the results of bacterial analysis are inconclusive, follow-up sampling is repeated as soon as possible.

Sampling

As per EPA guidance, samples are collected in water knee deep (approximately 0.5 meters), and 0.3 meters below the surface. The Virginia Department of Health's Beach Monitoring Protocol provides general guidelines for sampling procedures (as well as orientation on data averaging and the interpretation of results and on issuing and lifting swimming advisories). Samples are maintained refrigerated on 'wet' ice and are delivered to the laboratory for processing within six hours of collection.

Samples are collected on the regular monitoring day, rain or shine, unless conditions are dangerous to sampling staff. (If a decision is made not to sample because a violation of the standard is expected [e.g., heavy storm drain overflow], the beach is posted with a swimming advisory.) Samples are collected and transported in the same way at all sites. The sites are approached on foot and sampled from the beach. All the samples are grab samples, using sterile bottles that are supplied by the laboratory doing the bacterial analysis.

Whenever the Water Quality Standard is violated at a site, Dr. Charles Hagedorn of the Department of Crop and Soil Sciences at Virginia Polytechnic Institute and State University is sent supplemental samples for bacterial source tracking. Fluorometric studies are also performed on these supplemental samples twice per season. In addition, Dr. Hagedorn's enterococci results, using both the Membrane Filtration (MF) and Enterolert (MPN – Most Probable Number) methodologies, are subsequently compared to results from the local laboratories using the same method.

Duration

Beach monitoring sites are considered permanent, fixed sites of the VDH Beach Monitoring Program. Sampling will continue as long as funding is available. As mentioned above, the sampling is conducted from mid-May through the September swimming season.

Core and Supplemental Water Quality Indicators

The indicator organism used for estuarine and marine beaches is enterococci. Laboratory analysis of enterococci levels in beach water samples is conducted using EPA approved methods. Beach monitoring stations are specifically sampled for enterococci. Additional measurements of air and water temperature, dissolved oxygen, pH and salinity are taken at each of the beach sites during each visit.

Quality Assurance

A Quality Assurance Project Plan is currently being reviewed by EPA Region 3. As mentioned above, the Virginia Department of Health provides uniform guidance for sampling procedures, as well as orientation on data averaging and the interpretation of results and on issuing and lifting swimming advisories in its Beach Monitoring Protocol. The general SOP used for field sampling is Standard Methods, 9060, Samples Collection, 20th Edition (pp. 9-19 through 9-21). More specific SOPs for laboratory analyses of bacterial (enterococci) samples are produced by the individual laboratories performing the service (e.g., the Newport News Waterworks SOP for the Enterolert methodology). As mentioned above, an additional effort to maintain QA/QC consists of collecting grab samples from each site with bottles supplied by the same laboratory doing the subsequent bacterial analysis.

There is an annual Quality Assurance/Quality Control training program, conducted by the Beach Monitoring Coordinator, for all field personnel and their supervisors. Training is given in operating and calibrating equipment, the proper way to collect samples, and how to fill out lab forms for clarity, consistency and completeness. Additional training is provided on how to troubleshoot and correct equipment malfunctions, and on how to report results. In-the-field training is also given at the same time.

Data Management

The VHD receives weekly data reports by e-mail, with attached Excel spreadsheets, from each local health department on the same day they receive the results from their respective laboratories. Lab reports are also sent to VDH by e-mail, fax or conventional mail. Timely data submission is emphasized so that the VDH Beach WebPage can be updated as soon as data are available. This is especially true when swimming advisories have been issued. Personnel at the Division of Zoonotic and Environmental Epidemiology aggregate the data on an Excel spreadsheet as soon they are received. The VDH subsequently uploads the data from the Excel spreadsheets into an ACCESS database for long-term data storage.

Data are periodically shipped to EPA, via CDX for STORET, in an XML schema utilizing formats specified in the data user's guide (Beach Monitoring Data User Guide, EPA-823-R-03-004, May 2003) provided by EPA. So far, EPA has indicated that they wish to receive the data on a yearly basis, by January 31. VDH sent 2003 bacteria monitoring data to EPA at the same time that they provided general program information on beach locations, beach extents, state and local beach monitoring contacts, beach advisory authorities, monitoring data fields, and swimming advisory fields, in December of 2003. This information was submitted to meet the original grant requirements. BEACH monitoring information is currently maintained in a number of different databases, as has been requested by EPA.

Data Analysis/Assessment

Swimming Advisories: The Virginia Department of Health compares measured bacterial concentrations with the Virginia Water Quality Standard for enterococci. The results from several simultaneously collected samples at the same beach unit may be united into a single arithmetic average for comparison with the Standard, and for subsequent evaluation for issuing swimming advisories. The single sample, Instantaneous Standard concentration for enterococci is 104 colony forming units (cfu)/100ml. Samples above this level are in violation of the Virginia Water Quality Standards. A single violation of the instantaneous standard is sufficient to issue a swimming advisory for the beach in question.

If there is a violation of the standard, the local health department contacts the locality in which the beach is located to inform them of the advisory and the beach is posted with a swimming advisory sign. A press release is issued to notify the public, and a follow-up water sample is taken and delivered to the lab as soon as possible. Specific procedures for this process are documented in the VDH Beach Monitoring Protocol.

305(b)/303(d) Assessment and Reporting: The specific 305(b) assessment methodologies for using (1) swimming advisories and/or (2) the enterococci concentration data from the BEACH Monitoring Program was discussed by VDH and DEQ. The final decision on appropriate methodologies is incorporated into the Assessment Guidance Manual for the 2006 Integrated 305(b)/303(d) Report.

Reporting

If bacteria levels exceed the Water Quality Standards, the beach is posted with a swimming advisory sign and the public is notified through press releases to local newspapers and posting of results on the VDH

web page http://www.vdh.virginia.gov/epi/dzee/beachmonitoring/index.asp

The results of swimming advisories and all bacterial data collected by the BEACH Monitoring Program are communicated to DEQ for use in the agency's biennial Integrated 305(b)/303(d) Report.

Programmatic Evaluation

At this time, the BEACH Monitoring Program is in a period of ongoing evaluation by EPA, primarily due its recent development. VDH participates in weekly conference calls and annual meetings with EPA to review the Beach Monitoring Program in Virginia. The Beach Monitoring Program is grant funded, and reviews of the yearly proposals, progress reports, and database submissions are mechanisms for programmatic evaluation by EPA. Within VDH, there are monthly Beach Monitoring conference calls between the Division of Zoonotic and Environmental Epidemiology and the participating health districts, and weekly reviews of data from each participating health district by Virginia's Beach Coordinator.

General Support and Infrastructure Planning

The BEACH Monitoring Program is a federally funded program. Yearly budgets are prepared well in advance to meet proposal submission deadlines established by EPA. VDH has already received three Development Grants and two Implementation Grants from EPA. Future changes in methodologies will depend upon EPA recommendations, and expansion of the current program may occur in response to the opening of new public beaches or their identification by local health districts.

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Citizen and Non-Agency Water Quality Monitoring Program

Citizen water quality monitoring has been a stewardship activity in Virginia for many years. As the quantity and quality of water monitoring data collected by entities other than DEQ has increased, so has the interest in using these data for more than background information in Virginia's water quality assessments. New citizen organizations continue to establish stream monitoring programs with technical and financial support from the Commonwealth. However, other non-agency monitoring programs are either starting up or maintaining their operations independently of DEQ.

In August of 2004, the Virginia Department of Environmental Quality (DEQ) created the Water Quality Data Liaison (WQDL) staff position. This was in response to the increase in water quality monitoring data submissions by non-DEQ sources in addition to citizen monitoring. The WQDL is charged with requesting and reviewing water quality data from these non-DEQ sources. The WQDL is also responsible for providing technical support to citizen monitoring organizations along with administering the citizen monitoring grant program.

Starting with the 2004 assessment report, DEQ began to use chemical monitoring data collected by citizen groups and other non-agency sources which met DEQ Quality Assurance and Quality Control (QA/QC) protocols for determination of attainment of Water Quality Standards. This QA/QC process ensures that citizen organizations and other non-agency data sources are using the same sampling and testing methods that DEQ staff use. This ensures that data results would be similar or identical to the results a DEQ scientist who had sampled at the same time and location would have found.

Citizen Monitoring:

The Virginia Save Our Streams Program of the Virginia Division of the Izaak Walton League of America (VA SOS) took the lead in establishing relations with the Department of Environmental Quality (DEQ) and the Department of Conservation and Recreation (DCR) to develop a statewide citizen monitoring program. This was done through two separate letters of agreement signed by each agency in 1998 and was furthered by a three-way agreement signed in 1999. A new letter of agreement was signed in April 2002 to renew this collaboration and to add a new signatory, Alliance for the Chesapeake Bay, to the partnership. In 2002, the Virginia General Assembly passed legislation that established the Virginia Citizen Water Quality Monitoring Program in the Code of Virginia (§62.1-44.19:11). Additional citizen monitoring information can be found on the DEQ website: http://www.deq.virginia.gov/cmonitor.

The position of the Water Quality Data Liaison was created to provide guidance and technical support to citizen monitoring organizations, facilitate communication among citizen monitoring organizations and other agencies, promote the use of citizen water quality monitoring data in a manner consistent with the data use goals of the organization and encourage additional monitoring efforts. The Water Quality Data Liaison is also responsible for soliciting all non-DEQ sources of water quality data available for DEQ use.

In addition, a budget amendment in the 1999 Virginia General Assembly Session created the Citizen Water Quality Monitoring Grant Program to fund citizen monitoring activities when funding is available. This grant program has provided funding to 60 different organizations since 1999. The financial support from the Commonwealth has greatly enhanced both the quality and quantity of citizen-collected data provided to DEQ.

The citizen monitoring grant is one of the best tools that DEQ has available to enable citizen groups to generate DEQ-approved water quality data. This grant requires recipients to submit Quality Assurance Project Plans (QAPP) and follow procedures that are approved by DEQ. DEQ also offers review and assistance in the development of a monitoring program with a grant recipient. In return, citizen groups receive financial support, when available, for their monitoring programs.

Currently, DEQ has contacts with approximately 130 citizen monitoring organizations. Of these, 85 groups have an active water quality monitoring program and regularly work with DEQ. These programs vary in sophistication and in parameters monitored. Though not all citizen monitoring data may be used in the assessment report, all citizen-generated data is important to DEQ and characterize the quality of Virginia's waters.

Citizens monitor streams, lakes, and estuaries for a variety of parameters depending upon the goals of their program. Common ambient measures include any of the following physical and chemical parameters: water temperature, pH, dissolved oxygen, nutrients (various forms of nitrogen and phosphorus), or solids suspended in the water column. Biological parameters measured by citizen monitors often include benthic macroinvertebrates, E. coli bacteria, or chlorophyll *a*.

While all citizen-collected water quality data throughout the state are important, data used in this report were collected under documented protocols, standard operating procedures, and quality assurance/quality control methods as approved by DEQ for water quality assessment purposes. Data collected where the exact sampling location could not be confirmed by DEQ was not used in this assessment. Data collected by citizen volunteers that are not used directly for this assessment report are used to assist DEQ and other water quality agencies in prioritizing future monitoring and restoration work. Additional information associated with citizen monitoring assessment issues can be found in the 2006 Water Quality Assessment Guidance Manual found on the DEQ website: http://www.deq.virginia.gov/wqa.

In order to assist citizen monitoring organizations with developing monitoring programs, the Virginia Citizen Water Quality Monitoring Methods Manual was printed and distributed to organizations involved in water quality monitoring. This manual provides guidance to organizations on quality assurance/quality control procedures and protocols acceptable to DEQ for use in this assessment report. The manual can be found on the DEQ website: http://www.deq.virginia.gov/cmonitor/guidance.html.

As mentioned in the *Virginia Citizen Water Quality Monitoring Methods Manua*l, DEQ has three grades to assess citizen and other non-agency water monitoring data quality. These levels increase in rank from Level I to Level III based on the group following increasing levels of DEQ approved quality assurance protocols. The definitions and how groups can achieve each level are outlined below.

Level I - not approved by DEQ for assessment purposes. Monitoring and/or laboratory analysis does not follow DEQ sampling methods or quality assurance protocols. There is no Quality Assurance Project Plan (QAPP) or Standard Operational Procedures (SOP) on file.

- Data may be used by DEQ to identify sites that may need to have DEQ perform follow up monitoring.
- Data may be used for educational purposes.
- Data can notify DEQ of significant pollution events for environmental response.
- Samples that test for substances that are not identified under the Virginia Water Quality Standards list.

Level II - partially approved by DEQ. May be using a monitoring method similar to DEQ protocols but not fully approved by DEQ. Methods used by the group may be similar but not identical to methods used by DEQ for analyzing the water quality parameter. The monitoring group may have a DEQ approved QAPP and/or SOP on file.

- All uses as stated in Level I
- Could be used for 305(b) assessment purposes to identify possible waters of concern or healthy streams but will need DEQ monitoring data to confirm status (Category 3C or 3D).

Level III - approved by DEQ- Group follows DEQ testing protocols and quality assurance. Group sampling and laboratory testing protocols are approved by DEQ or DEQ approved accrediting authority. Group possesses a DEQ approved QAPP and SOP with no deviation from DEQ approved standardized methods (EPA methods, Standard Methods, etc).

- All uses as stated in Level II
- DEQ views this level of citizen data as if a DEQ sampler had collected and analyzed the sample. Citizen data that meets level III criteria will be used in the 305 (b) water quality assessment and for 303(d) listing of impaired waters.

For the 2006 assessment report, DEQ received data from 81 citizen monitoring groups totaling approximately 770 sites. As of the date of writing of this summary, 98 sites met Level I requirements, 328 sites met Level II, and 343 met Level III for at least one water quality parameter. This is the highest level of citizen monitoring data for assessment yet achieved.

In addition to the number of Level III sites, DEQ has also approved, for at least one parameter, the highest number of citizen monitoring organizations for Level III data. As of December 2004, DEQ had awarded Level III status to 34 of the 81 citizen monitoring groups who have submitted water quality data to DEQ. The desire of many groups to have DEQ use their data, the continued efforts by DEQ staff to help citizen groups to match DEQ protocols, and the Citizen Monitoring Grant Program, are all helping to increase the number of Level III data submissions.

Cooperative partnerships have enhanced relationships between state agencies and citizen monitoring organizations which has improved the quality and quantity of citizen-collected data for this report. This foundation is expected to continue and be built upon in the future.

DEQ would like to thank all of the organizations listed below for submitting citizen-collected data and supporting documentation for development of this report:

Alliance for the Chesapeake Bay
Audubon Naturalist Society
Appomattox River Water Quality Monitoring Program (coordinated by Clean Virginia Waterways and Longwood University)
Environmental Association for Senior Involvement
Friends of the Shenandoah River
Historic Green Springs, Inc.
Lake Anna Civic Association
Loudoun Wildlife Conservancy
Staunton-Augusta Chapter of the Izaak Walton League
Chesapeake Bay Governors School (coordinated by the Tidewater Resource Conservation & Development)
Virginia Save Our Streams Program of the Virginia Division of the Izaak Walton League of America

The Alliance for the Chesapeake Bay submitted ambient (chemical and physical) data collected by individuals and the following affiliate organizations:

Caledon Natural Area
Cat Point Creek Group
Cherokee Lake Association
Chesapeake Bay Foundation, York Chapter
Chesapeake Bay Youth Conservation Corps
Chippokes State Park
Eastern Shore Soil and Water Conservation District
Elizabeth River Project
Friends of Chesterfield's Riverfront
Friends of the Rappahannock
Friends of Scott's Creek
Friends of Stafford Creeks
George Washington's Birthplace National Monument
James River Association
James River Park
Leesylvania State Park
Mason Neck State Park
Mattaponi Indian Reservation
Tidewater Resource Conservation and Development Council
Westmoreland State Park
York River State Park

The Friends of the Shenandoah River submitted ambient (chemical and physical) data collected with the help of the following affiliate organizations:

Augusta River Monitors
Friends of the North Fork Shenandoah River
Friends of Page Valley
Friends of the Shenandoah River

Opequon Watershed Inc.
Warren County Water Monitoring Group

The Virginia Save Our Streams Program of the Virginia Division of the Izaak Walton League of America submitted benthic macroinvertebrate data collected by individuals and the following affiliate organizations:

Amelia County Landfill
Bluestone Watershed Committee
Buchanan Citizens Action Group
Buckingham Citizen Action League
Cowpasture River Preservation Association
Culpeper Soil and Water Conservation District
Douthat State Park
Elliott Creek Watershed Protection Council
Emory and Henry College
Environmental Education Center
Environmentally Concerned Citizens Organization
Friends of Page Valley
Friends of the North Fork of the Shenandoah River
Friends of the North River
Friends of the Pedlar River
Friends of the Rappahannock
Friends of the Rockfish River
Goose Creek Association
Grundy High School Earth Science Class
Headwaters Association
Holston River Water Quality Monitors
Hungry Mother State Park
J. R. Horsley Soil and Water Conservation District
John Marshall Soil and Water Conservation District
Kittrell Stream Team
Maury River Middle School
Maury River Monitors
Middle River Monitors
Mountain Stream Stewards
New River Monitors
North Fork Goose Creek Watershed Committee
Northern Virginia Soil and Water Conservation District
Pedlar River Institute
Piedmont Environmental Council
Radford University Green Team
Reston Association
Rivanna Conservation Society
Rivanna River Basin Project
Roanoke River Monitors
Skyline Chapter of Trout Unlimited
Stream Watch
Upper Rappahannock Watershed Stream Monitoring Program
Upper Tennessee Roundtable Monitors
Virginia's Explore Park
VT Department of Geosciences
Walker Creek Watershed Group
Warren County Chapter of the Izaak Walton League

The VA SOS program has a benthic macroinvertebrate citizen monitoring protocol that is widely used by many affiliate organizations. In 2000, VA SOS completed a two-year study, funded by DEQ, evaluating this protocol and developing a new protocol to more closely correlate with professional methods developed by EPA and used by DEQ. VA SOS began training volunteers in the modified protocol in 2001 and most volunteers have switched to this method. Data collected by VA SOS and affiliate organizations using both

methods were used in this assessment.

The VA SOS protocol is suitable for monitoring higher gradient streams with riffles typical of those found in the western part of Virginia. In response to requests from citizens located in the eastern part of Virginia, VA SOS has developed a protocol for low gradient, freshwater, non-tidal streams. At the time of this report, DEQ has not approved the low gradient freshwater streams for Level II or III purposes. For that reason, this data is not included in this report.

In the river basin summaries, several terms are used in the citizen monitoring descriptions that are defined as follows:

- *Ambient monitoring*: Monitoring for physical and chemical water quality parameters
- *Benthic macroinvertebrate monitoring*: Careful observations of the macro invertebrate (bottom-dwelling insects and crustaceans) community in a stream can give an indication of long-term water quality conditions.
- *Certified VA SOS volunteers*: VA SOS program volunteers that have gone through the training and testing process as identified in the VA SOS Quality Assurance Project Plan.

Other Non-Agency Water Quality Monitoring:

By broadening the scope of data requests beyond citizen monitoring, DEQ is expanding the pool of available resources to provide better monitoring and assessment coverage of the waters of Virginia. This increased coverage via non-agency sources will complement the monitoring done by DEQ. In future assessment reports ambient water quality data from previously untapped sources, such as ambient stream monitoring by wastewater treatment plants upstream of their discharge, will be included.

During the past several assessment reports, DEQ received water quality monitoring data from the United States Geological Survey (USGS). This data collected by the USGS follows strict adherence to EPA sampling methods and analytical procedures that is fully approved by DEQ. In addition, the United States Forest Service (USFS) and the National Park Service (NPS) submitted chemical and benthic macroinvertebrate data. This benthic data collected by the USFS and NPS strictly follow EPA benthic macroinvertebrate monitoring protocols that are similar to DEQ benthic monitoring methods.

Since the 2002 assessment report, additional non-DEQ agencies have begun submitting water quality data for assessment purposes. Most of data submitted for the 2006 assessment report comes from various federal, state, and local government agencies and select academic institutions.

The guidelines for accepting this data are the same as with citizen monitoring data. The institution must submit a QAPP that DEQ must approve and must pass routine inspections and laboratory audits by DEQ. Depending on the degree of compliance with the vetting of the sampling methods and test procedures, the data can either be used directly for assessment purposes or provide locations for future DEQ monitoring.

For the 2006 assessment report, the following non-citizen, non-agencies submitted water quality monitoring data:

City of Norfolk Department of Public Works
Chesterfield County Office of Water Protection
Shenandoah National Park Service
Sweet Briar College
Tennessee Valley Authority
United States Geological Survey
United States Forest Service
University of Virginia Shenandoah Monitoring Program

Current Efforts to Expand Non-Agency Surface Water Monitoring

DEQ is committed to expanding our use of non-agency monitoring data in future water quality assessment reports. This is primarily due to an increasing need for additional water quality data and the growth in the sophistication in water quality monitoring by non-agency groups. Currently, DEQ is working on

three projects to increase the agency's use of non-agency resources.

The first project currently underway is a voluntary monitoring initiative for wastewater treatment plants and other facilities that have a Virginia Pollutant Discharge Elimination System (VPDES) permit. This monitoring initiative will involve working with VPDES permit holders to request the facilities to voluntary monitor water quality upstream of their discharge area.

Many VPDES facilities have qualified staff and laboratory capability due to their routine monitoring of treatment plant effluent. Facilities can volunteer to help sample upstream sites and submit data to the WQDL on a yearly basis. A few facilities were approached in 2005 to begin monitoring using this approach. This initiative will begin to approach 1140 VPDES facilities statewide in 2006. The goal of this monitoring initiative is to have 120 VPDES facilities participate by December of 2008. These facilities are expected to provide Level III data because of routine inspections by DEQ as part of their permit requirements.

The second effort by DEQ is to develop guidance to give Level III status to citizen and other monitoring groups for benthic macroinvertebrate monitoring data. Currently, almost all non-agency and citizen monitored benthic macro invertebrate data is classified as Level II because the methods being used are similar but significantly different to DEQ or EPA protocols. Guidelines are being developed based on what other states are currently using when accepting non-agency benthic macroinvertebrate data. When the guidelines are completed in 2006, citizens and other non-agency groups monitoring for benthic macroinvertebrates will be better prepared to submit a QAPP and use sampling methods that more closely compare to DEQ methods. This will provide Level III status to these groups and increase our level of useable benthic macro invertebrate data for future assessment reports.

Finally, DEQ is working closely with water monitoring organizations to help find and identify new groups to contact to request data. One of the partners that DEQ is working with is the Virginia Water Monitoring Council (VWMC). The VWMC is a leading organization in Virginia that identifies partners in water monitoring by bringing together citizens, academia, private business, and government agencies. DEQ has a long standing relationship with the VWMC.

Recently the VWMC developed a database that contains known water quality monitoring efforts in Virginia. This database is accessible by going to their website http://www.vwrrc.vt.edu/vwmc. Though the database is currently being upgraded, it already contains information from many citizen monitoring groups, local government, universities, and other water monitoring groups DEQ is assisting the VWMC in the development of this database and in return, will be able to contact new organizations to request data from for future assessment reports.

Through these new efforts and our continuing efforts with citizen monitoring groups, DEQ will be able to utilize data that was previously unavailable or unknown in prior assessment reports. DEQ values the contributions of all non-agency staffs and citizen volunteers and will continue to support their monitoring efforts. With the gracious assistance from these organizations, DEQ is able to increase its monitoring coverage for this and future assessment reports.

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Freshwater Probabilistic Monitoring Program (ProbMon)

The Commonwealth of Virginia is rich in water resources with a wide variety of aquatic environments from fresh to salt, and mountain to coastal plain. The value of these resources is directly related to their quality. So, the question that needs to be asked is "How good is Virginia's water quality, and how does it vary across the State?" The Virginia General Assembly, environmentalists, citizens, and the USEPA have encouraged the Virginia Department of Environmental Quality (VDEQ) to address this question. Historically, VDEQ has done this through the 305(b) Report which is based on tens of thousands of targeted data points collected from more than a thousand stations in streams, lakes, and estuaries of the Commonwealth. However, it would take several times the existing financial and human resources to monitor water quality everywhere on an ongoing basis. The historical data set is considered non-random, and therefore the data cannot be used to develop statewide statistically valid distributions of conditions. While targeted sampling has great utility for monitoring regulatory compliance of pollution sources, identifying impaired waters, and for tracking local pollution events, it isn't appropriate to extrapolate the estimates to un-sampled waterbodies or other geographic areas of the Commonwealth. In order to answer these questions data should be obtained from sample locations that are randomly chosen where all points had an equal chance of being sampled. Consequently, in order to answer the question "How good is Virginia's water quality, and how does it vary across the State?", a new data set was needed.

In response to the need to statistically answer statewide and regional questions about water quality, VDEQ added Probabilistic Monitoring (ProbMon) to its freshwater monitoring program in 2001. The aim of ProbMon is to provide accurate statewide and regional assessments of the chemical, physical, and biological conditions of Virginia's water resources. Station locations have been selected randomly to allow the expression of water quality conditions in statistical terms. That means that along with estimates of how many river miles exceed a criterion, estimates of confidence in the numbers can be generated. For example, it is possible to determine the percent of streams having good water quality and measures of our confidence in that number. These methods are not limited to simple point estimates, but also allow descriptions of the true distribution of a parameter across a region and how these distributions differ between regions. This is very important for developing expectations for regions (setting criteria) and better understanding water quality problems on a statewide scale.

ProbMon's focus is on non-tidal, perennial streams in Virginia. VDEQ also has a tidal probabilistic monitoring program, and actively participates in both the Chesapeake Bay and Coastal 2000 Programs. VDEQ's ProbMon survey will collect data from approximately 300 stream locations over a five-year period. In the end, the survey will provide policy-makers and the public with estimates of the status of Virginia's aquatic resources with statistical confidence. It will also describe associations between indicators of natural and anthropogenic stress and aquatic resources. ProbMon will be used to statistically assess the Commonwealth's water resources on those non-tidal, perennial streams.

Monitoring Objectives

The primary objective of ProbMon is to answer the question asked above "How Good is Virginia's Water Quality and how does it vary across the state?" That seemingly simple question is actually quite complex. Water Quality conditions vary in time (short-term and long-term), space, and intensity. To add to the complexity, some of the variability is natural while some is caused by human activity. Another goal of ProbMon is to describe both the spatial variability and the cause of the variability. Specific objectives include:

1. Assess the condition of Virginia's freshwater resources.
2. Describe the natural condition in un-stressed locations and define reference conditions for different parts of the state.
3. Describe how parameters are distributed statistically
4. Describe how parameters are distributed spatially
5. Describe statistical trends over time.

These objectives will be interpreted into general and specific results:

General results will be graphics depicting percentages of river miles that are Good, Moderately Stressed and Severely Stressed specific to different parameters, regions, types of streams and land use patterns.

Specific results will attempt to find emerging patterns in the data such as:

1. Determination of the most common ecological stressors
2. Describe how these stressors are distributed across the state
3. Identify regions or types of streams that are most affected by either naturally occurring or anthropogenic stressors.
4. Describe reference conditions for different areas of the state.
5. Describe relationships between parameters and determine relative risks

Uses and Limitations of the data

These data will allow us to communicate what problems are commonly affecting Virginia streams and the relative risk these problems pose. Water Quality Managers will be able to use this information to make informed decisions concerning what issues need to be addressed and in setting new water quality criteria.

The sampling design allows for answering a wide variety of questions in addition to those listed above. Some of the potential questions that can be answered include:

- *Assessments:* "Approximately how many river miles are impaired and what are the major stressors?"
- *Policy:* What issues do the data indicate need to be addressed?
- *Biomonitoring:* How do biological parameters respond to specific stressors and what is the natural condition?
- *Permitting:* What channel shapes are appropriate for stream modeling in specific regions?
- *Standards:* How do parameters vary between regions of the state and what is the natural condition?
- *Waste and Pollution Response*: For parameters without established standards targeted sites can be interpreted compared to the statewide and regional distributions.
- *Air:* What is the effect of air pollution (like acid rain) on water quality parameters?
- *Resource documentation:* What is the statewide distribution of specific aquatic habitats?
- *Virginia Water Protection Program:* What is the expected sediment type in a specific stream or region?
- *Management:* Are environmental management programs working to protect our resources?
- *TMDLs:* How bad is a specific site compared to the statewide condition?

These questions are important and are not answered by other monitoring programs. While probabilistic monitoring has many uses it does not replace targeted monitoring. Probability based designs cannot be relied on to provide data on specific known problems, to model TMDLs, nor is it the best way to find problems for 303(d) listing. While it does provide an estimate of how many river miles are impaired probabilistic monitoring does not tell us where those impairments are. The probabilistic design is also limited in its ability to examine short-term temporal variability. Because sites are only visited twice and only biological data are replicated, it isn't possible to examine short term variability of non-biological parameters. On the other hand we will be able to examine statewide trends over long time periods by looking at trends in statewide curves.

Another limitation of the data is in defining the extremes or worse case conditions. It will take several years to randomly sample the most extreme conditions for some parameters. Therefore, graphs should be interpreted as good representations of the average condition, but the extremes are likely worse than graphed. Also the rarer a parameter is in the environment the longer it will take for us to randomly sample a site that is impaired by it. For this reason early reports have focused on the most common stressors. As the database fills in we shall be able to provide data on the rarer parameters and more accurately describe the extreme conditions.

Probabilistic Monitoring Design

Virginia examined several options before choosing a probabilistic monitoring design. An EMAP-based (EPA's Environmental Monitoring and Assessment Program) design was chosen because of the support provided by EPA and the potential for the data to be utilized in nationwide studies. EPA worked with DEQ to ensure the design fit our needs, and could still be used in nationwide analyses.

ProbMon is an unequal probability survey meaning that the elements of the target population are not sampled with equal frequency. The target population is all non-tidal perennial streams in Virginia, and

stratified by stream orders. The Strahler stream ordering system is a general way of describing the size of a stream or river (Strahler 1964). The smallest continually flowing headwater streams are called "first order". When two first order streams join to form a larger stream it is termed a second order stream. Two second order streams join to form a third order, and so on. Smaller streams entering a higher-ordered stream do not change its order number. The size or order of a stream was selected as the basic selection element to avoid over selecting the more common stream sizes. For example, because 1st order streams make up 65% of Virginia stream miles and are four times as common as 2nd order streams, 1st order streams are four times as likely to be randomly selected by a simple random design. Because high order streams are rare, they could be so under sampled that their statistics would be meaningless. Large rivers are important resources, thus it was decided to include an assessment of them as well as the smaller streams. Thus, the commonness of stream orders 1 through 4, and orders 5-7 combined was used to weight the choice of samples so that all orders were approximately equally sampled.

How were ProbMon Stations Selected ?

Probabilistic sampling sites were randomly selected by EPA/ORD in Corvallis, OR using a random tessellation stratified survey design (Stevens 1997). In this method, an EMAP grid of hexagons is placed over the Commonwealth (Figure 2.1-1). This grid ensures randomization and spatial distribution of sampling locations. The base density is one grid point per 640 km^2. The 640 km^2 hexagons are subdivided into 7 hexagons of 90 km^2 each. The 90 km^2 hexagons are subdivided into 7 hexagons that each covers 13 km^2. Finally, within the 13 km^2 hexals there are 7 hexagons that cover 1.8 km^2 of land surface. In Virginia, the sample areas were the 13 km^2 hexals whose edges are defined by the 1.8 km2 hexagons. Virginia's ProbMon design can be described as a 7 x 7 x 7 fold enhancement. Inside each 13 km^2 hexal the stream segments were designated by Strahler stream order and each segment was assigned a unique code. A stream segment is a stretch of stream between its union with a tributary and the next union upstream. These segments were randomly arranged onto a line as demonstrated in Figure 2.1-1. The final line represents the length of all streams from inside the seven 1.8 km^2 hexagons. Sampling locations were randomly chosen along this final line.

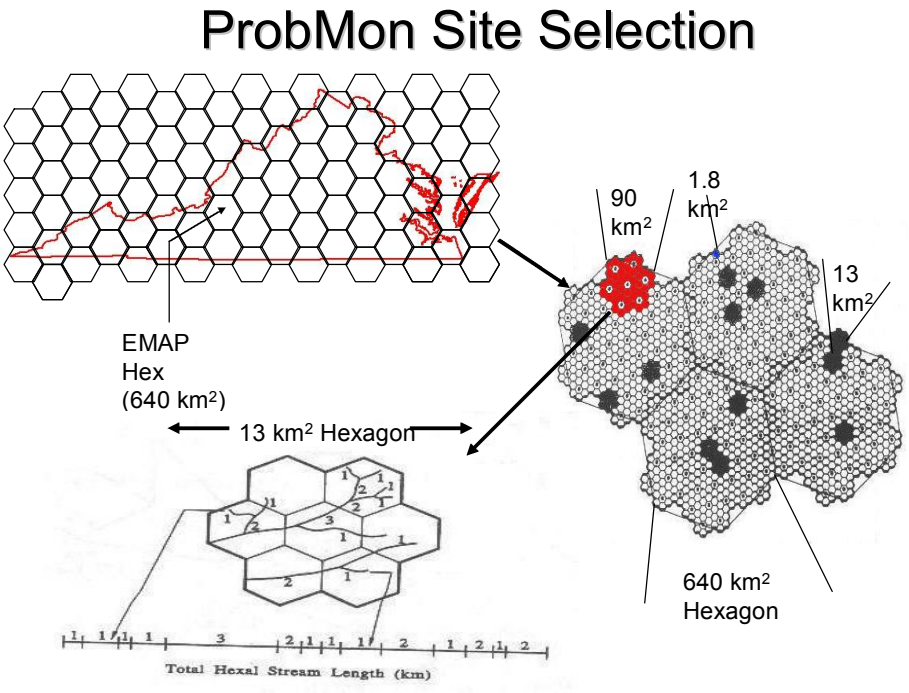

Figure 2.1-1

Sampling Protocols and Parameters

Sample sites are given as points on a stream (termed "X") but the site is actually sampled within a reach that is 40 stream widths long (150m minimum, 800m maximum). The reach can slide upstream or

downstream to avoid major tributaries or other natural barriers to sampling. However the reach should not be adjusted to avoid manmade changes to the channel. The point X is always located within the reach. Sites are visited twice during the year. In the spring water chemistry is collected as near to X as possible. Benthic samples are collected from the most productive habitat(s) in the reach. Sites are again visited in the autumn during which benthic communities are sampled a second time along with an intensive physical habitat assessment that is performed over the entire reach.

Water chemistry parameters have varied during the project but approximately 80 chemical and physical parameters are measured at each site. During some years the parameter list has been larger because we performed special studies that required additional parameters and over time we have adjusted the list to include new parameters. Water and sediment samples are sent to the Virginia Division of Consolidated Laboratory Services in Richmond, Virginia for analysis.

ProbMon collects biological monitoring using EPA's Rapid Bioassessment Protocols (RBP). ProbMon biomonitoring differs dramatically from VDEQ's historical approach in which monitored sites were paired with a single reference site characterizing the expected condition of undisturbed biota. A goal of VDEQ's biomonitoring program is to increase the number of reference sites across the State so that reference conditions can be developed and incorporated into a multi-metric index for macroinvertebrate communities. The data collected at random sites in the ProbMon program will accelerate this process and help determine reference conditions throughout the Commonwealth.

The Virginia ProbMon survey includes a habitat assessment component to determine the percent of non-tidal streams that show habitat degradation, as well as the percent that have exceptional habitat quality. Habitat data are collected using the RBP (Rapid Bioassessment Protocol) visual habitat assessment methods. In addition, biologists utilize selected parts of the EPA EMAP habitat assessment methods to allow calculation of relative bed stability, and quantification of embeddedness and mean substrate size.

Another part of the freshwater ProbMon program is calculating land cover upstream of ProbMon sites. The land surrounding a water body can significantly impact the in-stream water quality, altering the physical habitat and biological community. VDEQ can create a filtering matrix (which includes habitat and chemical data) to identify potential reference sites using Land Cover data. As ProbMon evolves, the quantity and variety of habitat data collected will expand to better define the range of physical habitat, and to allow the detection of relationships between physical habitat, biological communities, land cover and water quality.

Data Representativeness

In addition, one freshwater ProbMon site per DEQ Region is randomly selected as a "carry-over" site each year. With seven DEQ Regional Offices, this represents a carry-over rate of approximately 10% (7/60 = 11.7%). Carry-over sites are also selected in such a manner that they include two sites from each of the 1st and 2nd Order stream classes (82% of stream miles in Virginia) and one site from each of the other sampling strata (3rd, 4th and ≥ 5th Order streams). Carry-over sites are sampled biologically (benthic invertebrates) and for all water column parameters except for toxics in both the spring and fall of two consecutive years. The information from these carry-over sites provides estimates of both within year (seasonal) and between year (annual) variations in water quality and will facilitate the interpretations of both annual and long-term (trend) results.

Quality Assurance

ProbMon follows the methodologies described in Probabilistic Monitoring (http://www.deq.virginia.gov/water/probmon.pdf). ProbMon follows all VDEQ Quality Assurance/Quality Control (QA/QC) protocols and reports to the QA/QC Coordinator Gary Du.

Data Management

All water chemistry data is stored in VDEQ's Comprehensive Environmental Data System (CEDS). Using Oracle Discoverer, the water chemistry data are retrieved as an Access database file and put into an ArcView 3.2 Geographic Information System (GIS) database to generate maps. All biological and physical habitat data is stored in the Ecological Data Application System (EDAS), an Access database developed by TetraTech. The ProbMon data in EDAS was queried and merged into the GIS database with the chemical

data. Migration of the data to GIS makes it possible to identify the ecoregion of stations, adjacent land use, and spatial patterns. All data was combined in an Access database to facilitate importing to SAS, R, SysStat or STATISTICA for box plots, and exporting to text files for the CDF curves.

Reporting Requirements

The ProbMon work committee plans on organizing and reporting on probabilistic data yearly. ProbMon reports help meet requirements of the Water Quality Monitoring and Information Act (WQMIRA 1997) and the JLARC Review (1996). JLARC and WQMIRA specifically encouraged an increase in chemical and biological monitoring, statistical analysis of monitoring data, and statewide comparisons and sampling for all water quality criteria. A ProbMon report is planned in the future that will communicate useful information to the general public. Virginia will have a comprehensive report on the first five years of data in the 2008 305(b)/303(d) Integrated Report. VDEQ staff has made presentations about the program at national and regional conferences and will continue to do so.

Periodic Review of Program

ProbMon is subject to periodic internal and external reviews. Insightful discussions have occurred with Virginia's Academic Advisory Committee, EPA and DEQ staff members regarding future ProbMon goals. Minor adjustments are still being made to the program and many trial projects have been performed. Cost has been a major determinant in making permanent program changes. DEQ is currently looking for funding sources to incorporate fish and algae communities into our freshwater ProbMon program.

General Support and Infrastructure

The Commonwealth of Virginia and EPA 106 grants and other grants such as the Wadeable Streams Assessment Grant currently pay for all ProbMon activities. Regional monitoring staffs collect all of the necessary data and regional assessment staffs perform data analysis and produce ProbMon reports. EPA has provided support in terms of training, technology transfer and design.

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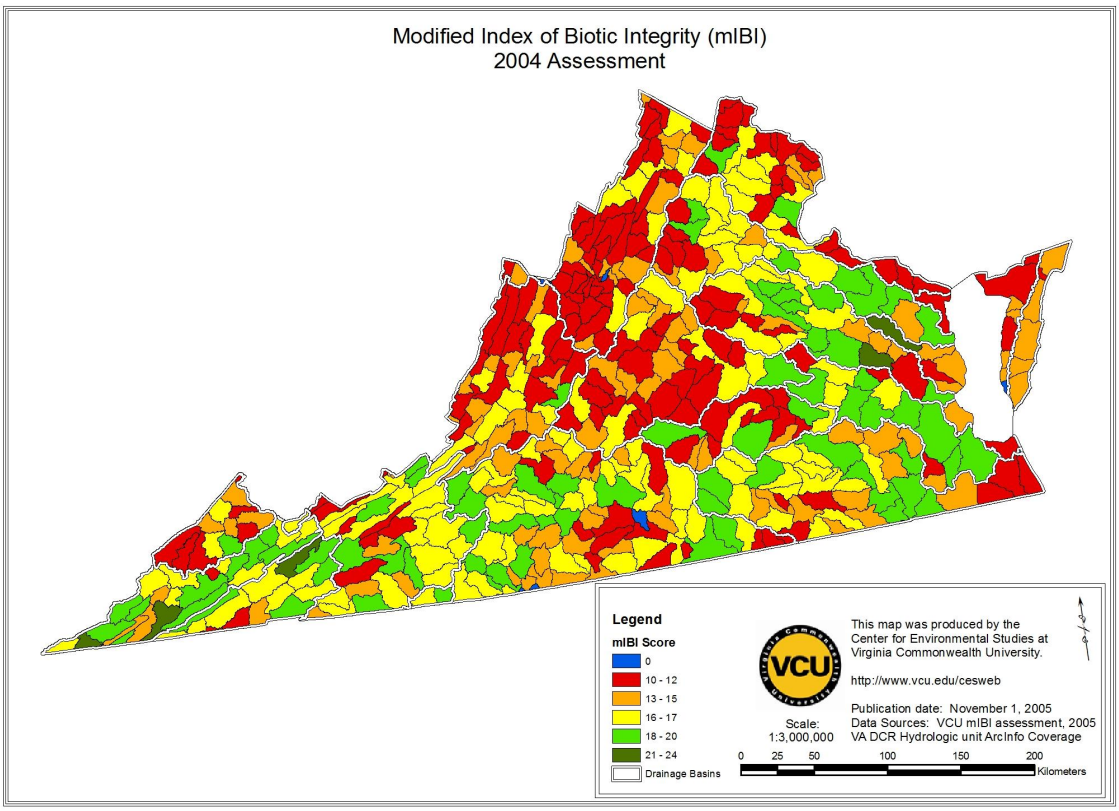
Other Monitoring and Assessment Initiatives

INteractive STream Assessment Resource (*INSTAR*)

Background

A key role of Virginia's natural resources agencies is the identification, restoration, and protection of streams, rivers, and riparian corridors that contribute important ecosystem services or represent significant ecological resources. Challenges associated with these important efforts include: 1) development and application of objective, quantitative, and diagnostic stream assessment protocols and 2) defining a set of measurable and appropriate stream conditions, based on empirical data, as goals for restoration and protection efforts. Both of these challenges are dependent on an understanding of, and comparison to, relevant reference conditions that describe accurately and quantitatively the ecological potential of streams and rivers within a specific region. In Virginia, the lack of relatively undisturbed streams to serve as reference systems is especially problematic in the Coastal Zone, Piedmont, northern Virginia, and the Shenandoah Valley, and compromises stream assessment and protection activities for these regions.



INSTAR-based classification of 494 watersheds (HUCs) based on 2004 modified Index of Biotic Integrity (mIBI) scores for stream health assessment. The mIBI score ranges between 6 and 30; watersheds with scores > 17 are characterized by streams with generally high biotic integrity. The 2004 statewide assessment is based on approximately 150,000 records, including quantitative and qualitative data. Several small watersheds have no data for 2004 and are scored 'zero.'

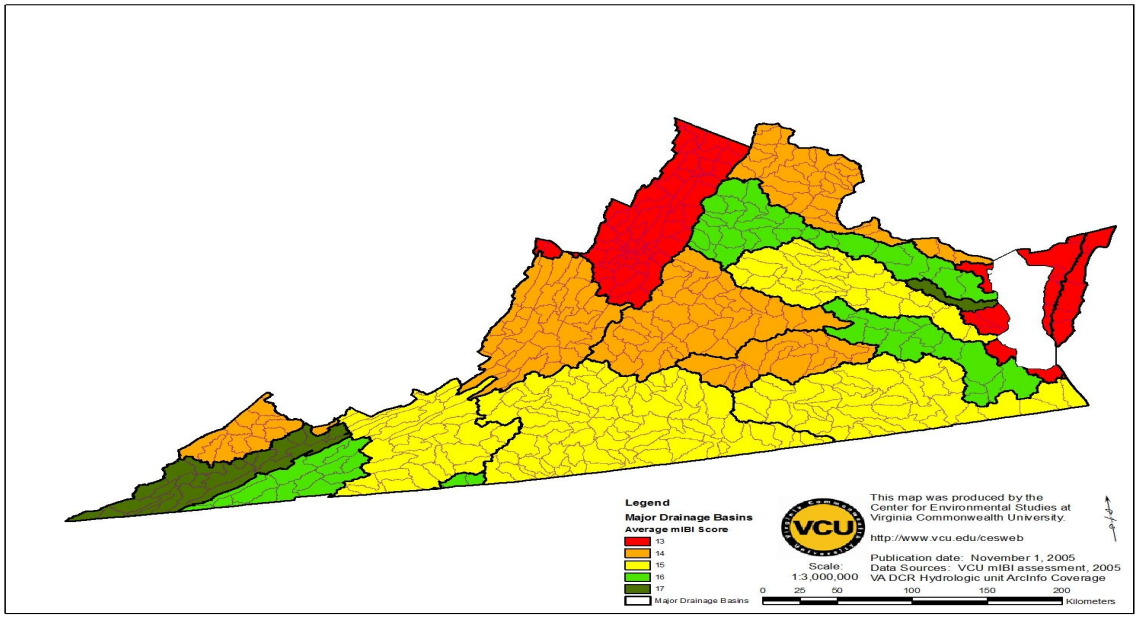
Recent studies in Virginia and elsewhere also suggest that results from standard stream assessment protocols (e.g. Rapid Bioassessment Protocols *versus* Indices of Biotic Integrity *versus* geomorphologic stream classification) often present conflicting views of stream health or status, even when the data on which assessments are based are temporally and spatially synoptic. The lack of agreement among standard stream assessment methods is problematic and may limit the appropriate application of these widely-used protocols, even where valid, regional reference conditions are available. Furthermore, current approaches to stream assessment may not support useful comparisons of conditions across broad spatial (i.e., geographic)

scales or among major watersheds.

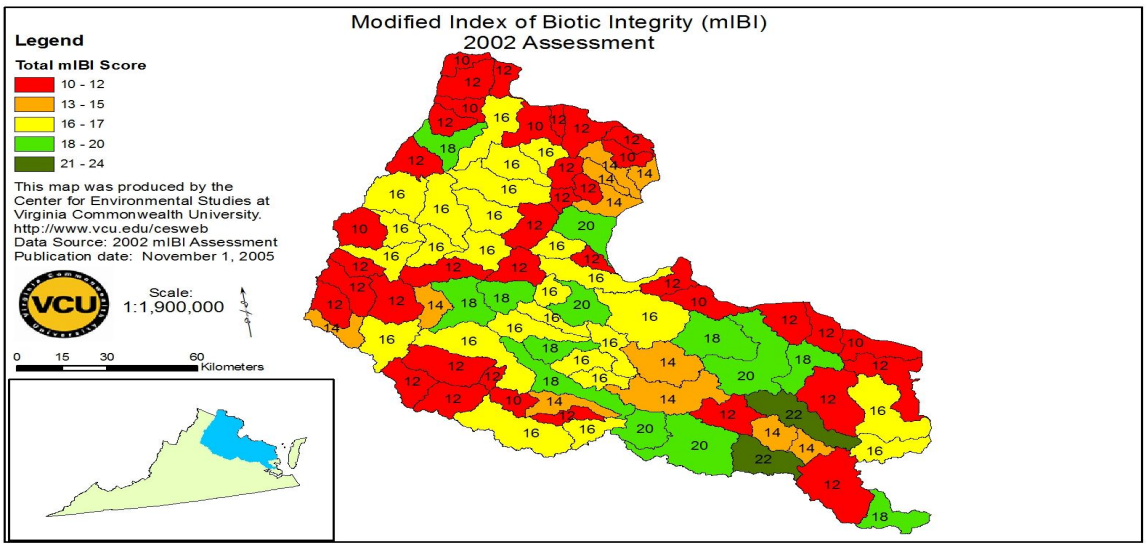
A New Approach to Stream Assessment

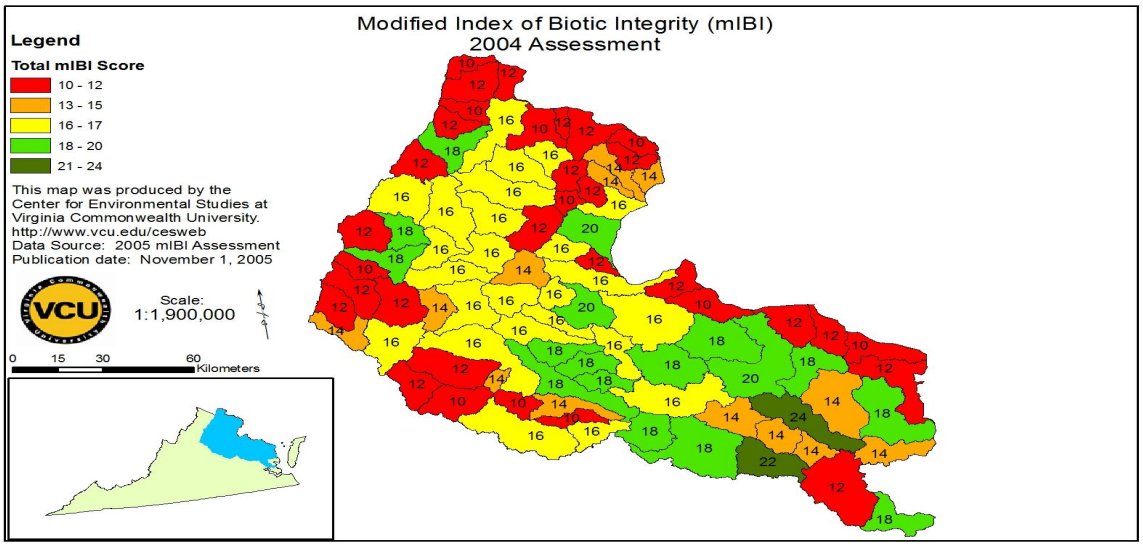
In response to the problems outlined above, Virginia Commonwealth University, the Virginia Department of Conservation and Recreation, and the Coastal Management Program of DEQ initiated a multi-phase project to develop an integrative, objective, and statistically valid stream health assessment application. The project uses high quality archival data, combined with extensive, new data collected by the VCU stream assessment team, to develop a broad suite of georeferenced databases of aquatic resources, including fish and macroinvertebrate communities, instream and riparian habitat, and geomorphological data. These databases are the foundation for the ***IN***teractive ***ST***ream ***A***ssessment ***R***esource (***INSTAR***) application: an online, interactive mapping and database application designed to quantitatively assess stream conditions based on comparisons among a suite of integrative, multimetric indices and 'virtual' reference stream models.

INSTAR**,** and the extensive aquatic resource database on which it runs, were developed to support a variety of stream assessment, management and planning activities aimed at restoring and protecting water quality and aquatic living resources throughout the Commonwealth. The project is currently focused on developing an aquatic resources (blue infrastructure) database and stream health assessment protocols for Virginia's portion of the Chesapeake Bay watershed. In addition, regional reference stream models (i.e., *virtual* streams) for both non-tidal and small to medium-sized tidal tributaries will be developed as criteria for prioritization of candidate streams and watersheds for protection and restoration, objective and quantitative performance measures, and as a decision support tool for environmental planning and implementation. The *INSTAR* program (http://instar.vcu.edu) and related applications developed by VCU leverage cutting-edge, information technologies (e.g. MS SQL, ArcIMS, ArcGIS Server) and an expanding database of high-quality, geospatial information to conduct both statewide (hydrologic unit scale) and site/reach specific assessments of stream and river health throughout the Commonwealth. Currently, *INSTAR* has compiled information on approximately 1,300 Virginia streams and *INSTAR* databases comprise over 150,000 records, including a substantial amount of new data for the Coastal Zone.



INSTAR-based classification of major Virginia river basins based on 2004 modified Index of Biotic Integrity (mIBI) scores for stream health assessment. The mIBI score ranges between 6 and 30; basins with scores < 14 (e.g. Shenandoah) are characterized by streams with generally low biotic integrity. In contrast, two basins (Dragon Run/Piankatank and Clinch) are dominated by streams with comparatively high biotic integrity **.**





The current (2004) mIBI stream assessment includes considerable new INSTAR data not available for the 2002 mIBI assessment. For a representative section of the Virginia Coastal Zone (above), the effect of these additional data on watershed-level stream assessments was substantial. Approximately one-third of the watersheds (HUCs) were classified differently in 2004 (lower map), compared to classification by the same mIBI protocol in 2002 (upper map), and there was a significant correlation between the number of additional records and the probability of a change in the mIBI stream health score in 2004. This finding suggests that accurate, statewide prioritization of streams and watersheds are influenced strongly by the quality and quantity of available data.

Methods

Probabilistic study reaches for *INSTAR* sampling are selected through a statistically powerful, stratified (by stream order) random design. Within each geo-referenced reach (150-200 m), fishes are sampled quantitatively using electrofishing equipment (backpacks, tote barge units, boats) and standard methods.

Backpack and tote barge sampling is performed throughout the entire reach in a single pass. Boat electrofishing may include additional sampling effort depending on stream width and habitat variability. All fishes are identified to species in the field, checked for anomalies, and released.

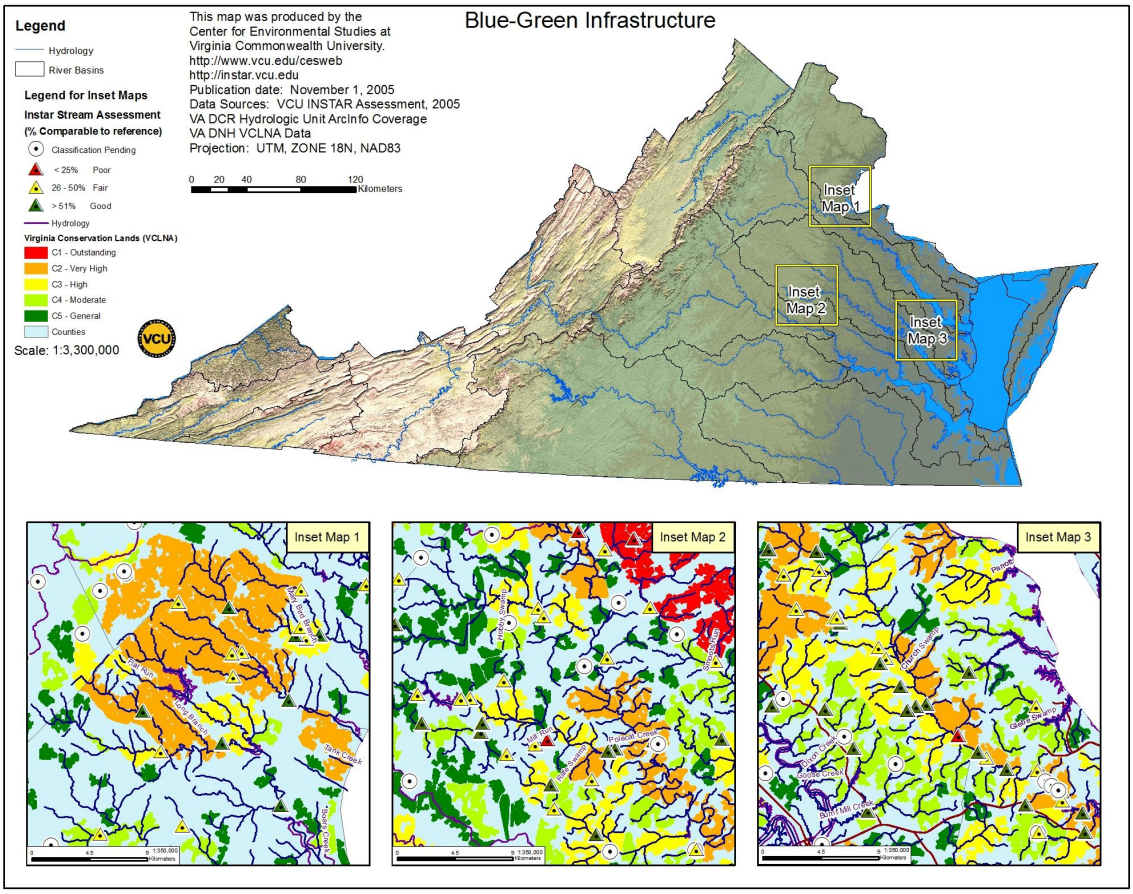
Macroinvertebrates are collected using modified EPA Rapid Bioassessment Protocols (RBP III) for multiple habitat collections using D-frame dipnets. Each major stream habitat type is sampled separately in proportion to its presence in a stream; those samples are composited into one sample representing the

stream reach, and macroinvertebrates are then enumerated and identified in the lab to the lowest practical taxon, generally at the genus level. Data are compiled in Access® databases and application macros within INSTAR calculate over 50 separate metrics and ecological variables, including those typically generated for the Index of Biotic Integrity (IBI), Rapid Bioassessment Protocol (RBP), Rapid Habitat Assessment (RHA), and Rosgen-type stream morphology classification. Variables and metrics are then subjected to ordination and cluster analysis using unimodal models (e.g. correspondence analysis (CA), detrended correspondence analysis (DCA), and canonical correspondence analysis (CCA)) and linear response models (e.g. principal components analysis (PCA), multiple regression techniques). The site scores (i.e., coefficients from the final response model) are entered as the response variable and significant ($P<0.05$) biotic and abiotic variables and metrics are entered as explanatory variables, and used to develop a series of reference stream models (i.e., *virtual* streams). Gower's similarity index was used to compare empirical scores obtained from sampled stream reaches to the appropriate virtual reference stream, generating an index of stream health as a measure of percent comparability to the appropriate (*virtual*) reference condition model. High percent comparability scores (> 75%) are assumed to represent streams with high ecological integrity. Current reference stream models for upper and lower Coastal Plain streams include variables representing fish and macroinvertebrate assemblage structure, instream habitat, and geomorphology, and have substantial explanatory power (R^2 up to 0.74). This integrative approach eliminates many of the limitations typically associated with traditional bioassessment methods (e.g. RBP, IBI), including lack of appropriate reference sites and stream classifications that are based on a single ecological component (e.g. biotic *versus* abiotic, fishes *versus* macroinvertebrates) that may not be diagnostic under many conditions.

Selected 'universal' metrics (e.g. combined native species richness, percent of pollution-tolerant species, combined non-indigenous species richness) are also used by *INSTAR* to generate a modified Index of Biotic Integrity (mIBI) that classifies each of Virginia's 494, 14-digit watersheds (hydrologic units, HUCs) as a function of stream health, using both quantitative and qualitative (species occurrences) records available for the watershed. Using these two novel approaches, INSTAR is able to support integrated stream health and watershed condition assessments at broad (statewide mIBI classification of HUCs) and fine (percent comparability to virtual reference stream models) geospatial scales. Appropriate quality assurance and control (QC/QA) procedures are followed for all *INSTAR* field and laboratory protocols.

Utility of *INSTAR*

The *INSTAR* application (http://instar.vcu.edu) is an interactive, internet-based (ArcIMS) program that supports user-driven database queries, mapping functions, and quantitative biological and habitat assessments of stream reaches and watersheds, using algorithms and ecological models that compare selected sites to appropriate regional reference conditions. *INSTAR* is accessible from most computers via the internet and allows both technical and non-technical users to conduct sophisticated GIS and database tasks using an extensive stream database and multiple geospatial data layers. *INSTAR* is currently being used by a wide range of local, state, and federal agencies, academic researchers, and citizen-scientists. Funding for INSTAR has been provided by the Virginia Department of Conservation and Recreation, Virginia Coastal Management Program (DEQ), and NOAA.



INSTAR assessment of specific stream reaches is based on percent comparability to appropriate, regional reference stream models (i.e., *virtual* streams) described in the above text. Stream reaches with strong (>75%) reference comparability scores are characterized by high ecological integrity and exceptional physicochemical conditions. In contrast, stream reaches with poor (<25%) reference comparability scores exhibit degraded ecological integrity and compromised physicochemical conditions. By early 2006, the ecological health of approximately 600 stream reaches—primarily in the Virginia Coastal Zone—will be evaluated using the novel INSTAR approach, which integrates over 50 ecological (biotic and abiotic) variables and metrics to assess stream condition. By combining results from INSTAR with complementary approaches to classifying terrestrial landscapes (e.g. Virginia Conservation Lands Needs Assessment; Division of Natural Heritage), the Commonwealth has, for the first time, tools to analyze complex relationships among elements of the Blue Infrastructure (e.g. water quality and stream-dependent living resources) and the Green Infrastructure (e.g. riparian buffers and land use) across broad geographic scales.

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